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14. ABSTRACT
The United States Air Force School of Aerospace Medicine, Consultative Services Division investigated false neutron counts with the Berkeley Nucleonics Corp. Model 940-2GN surveillance and measurement radioisotope identification system (SAM 940-2GN). This portable instrument is a standard component of the Bioenvironmental Engineering (BE) 886H Allowance Standard. In the presence of high-activity gamma fields, it has been demonstrated that the SAM 940-2GN will report neutron counts erroneously, which is due to cross-talk within the detector, and can be thought of as a "false positive." This letter provides a prediction of false neutron response in high-activity gamma environments based on empirical data. Additionally, the letter gives a decision matrix so BE personnel can appropriately assess SAM 940-2GN neutron counts and avoid potential misclassification of a source as a neutron emitter.

15. SUBJECT TERMS
Occupational health, consulting, ionizing radiation protection, exposure, SAM 940-2GN, isotope, identification, portable, meter, contingency response, gamma ray, Berkeley Nucleonics, Scionix, contamination, health physics, health risk assessment, handheld, consultative letter, USAF School of Aerospace Medicine (USAFSAM), customer support, 886H, sodium iodide, lithium iodide, scintillator, cross-talk, interference, equipment, dose rate, count rate, neutron, bioenvironmental engineering, emergency, false counts, industrial hygiene, gCPS, nCPS, detector, RSO, safety, AFMSA

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DEPARTMENT OF THE AIR FORCE
SCHOOL OF AEROSPACE MEDICINE (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE OHIO

28 December 2012

MEMORANDUM FOR AFMSA/SG3PB
USAF Radioisotope Committee Secretariat
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FROM: USAFSAM/OEC
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SUBJECT: Consultative Letter, AFRL-SA-WP-CL-2012-0069, Assessment of SAM 940 Cross-Talk Between Lithium Iodide (LiI) and Sodium Iodide (NaI) Scintillators

1. INTRODUCTION: At the request of the Air Force Medical Support Agency, USAF Radioisotope Committee Secretariat, the United States Air Force School of Aerospace Medicine, Consultative Services Division (USAFSAM/OEC) investigated reports of false neutron counts on the Berkeley Nucleonics Corporation Model 940-2GN surveillance and measurement radioisotope identification system (SAM 940-2GN). The purpose of this consultative letter is to inform the Bioenvironmental Engineering (BE) career field of potential errors with the SAM 940-2GN and how to interpret the data. This portable instrument is a standard component of the BE 886H Allowance Standard. In the presence of high-activity gamma fields, it has been demonstrated that the SAM 940-2GN will report neutron counts erroneously, which is due to cross-talk within the detector, and can be thought of as a "false positive." This letter provides a prediction of false neutron response in high-activity gamma environments based on empirical data (see Attachments 1 & 2). Additionally, the letter gives a decision matrix in Attachment 3 so BE personnel can appropriately assess SAM 940-2GN neutron counts and avoid potential misclassification of a source as a neutron emitter.

2. BACKGROUND

a. The SAM 940-2GN configuration consists of a 3- x 3-mm LiI(Eu) neutron scintillator coupled to a 51- x 51-mm NaI(Tl) gamma scintillator. The survey mode of the user interface provides instantaneous gamma counts per second (gCPS) and neutron counts per second (nCPS), as well as dose rates. Additionally, the isotope identification mode provides a 1-minute count rate in gCPS and nCPS, averaged over the acquired spectrum. In the identification mode, decay spectra are matched to a library of possible isotopes.

b. The susceptibility of the SAM 940-2GN unit to share energy between the gamma and neutron scintillators, and thus report false neutron counts, is a possible source of confusion for BE field operations. A test-based determination of this response can assist field operations by interpolating a useful formula (see Attachment 2).

3. EVALUATION METHODOLOGY AND RESULTS

a. USAFSAM/OEC used two SAM 940-2GN units to analyze the false neutron response to three common gamma emitters with varied gamma energies (see Attachment 1). These radionuclides, along with their associated major gamma energies line(s), were Ra-226 (186 keV), Cs-137 (662 keV), and Co-60 (1.2 MeV, 1.3 MeV). To avoid production of scatter radiation or characteristic x-rays, no beam shielding was used. Absence of shielding was necessary to assess energy dependence of nCPS values in various gamma fields.

b. For each radionuclide, 5 to10 averaged measurements were conducted on both units, where the averaging time was 1 minute. Count rate measurements were conducted on gCPS intervals that corresponded to predetermined dose rates. The range of dose rates was approximately 0.25-5.0 mrem/h for each radionuclide.

c. Prior to each use, the auto-calibration feature of the SAM 940-2GN firmware was executed. Further, 1-minute background measurements were taken in the locations of interest. No firmware updates were conducted in the course of the assessment. The auxiliary port was not utilized in any part of the assessment. Instrument calibrations were both current.

d. Energy dependence of nCPS values was found to be a differentiating factor among the three plots. Neutron count rates were directly proportional to both gamma energy and activity. The peak response observed corresponded to the Co-60 trial. The gCPS and nCPS resulting from this trial were used to derive an equation that estimates the SAM 940-2GN neutron response to high-activity gamma-only fields (see Attachment 2). This equation represents the worst-case of three radionuclides for a false neutron count rate.

e. The observed neutron cross-talk threshold was approximately 2K gCPS. Therefore, in gamma-only fields less than 2K gCPS, it is unlikely that cross-talk or erroneous neutron counts will appear.

f. For total false neutrons registered, the dose consequence was potentially significant. The highest false neutron rate observed for all radionuclides was 107 nCPS with the Cs-137 source. Assuming a neutron energy of 5 MeV, the corresponding neutron dose rate is approximately 17 mrem/h. It should be noted that false neutron counts were not factored into the SAM 940-2GN dose rate value. While these neutrons were demonstrated to be false counts, the potential faulty assumption that neutrons and/or a neutron emitter is present may confound surveys and subsequent BE actions such as health risk assessments and cleanup/disposals.

4. CONCLUSION/RECOMMENDATIONS

a. When using the SAM 940-2GN in high-activity gamma-only environments, it is recommended that precautions are taken to ensure successful correction of neutron data (see Attachment 3). The equation in Attachment 2 can be used to estimate predicted neutron count rate.

b. As always, radiation survey techniques and emergency response tactics should be conducted in a manner that limits personnel exposure to as low as reasonably achievable.

c. From the empirical data, erroneous neutron count rates are registered above gamma-only fields greater than approximately 2K gCPS. If the maximum neutron count rate observed was actually present, it would contribute a dose rate of about 17 mrem/h to the personnel exposed.

d. For reachback support and assistance with interpreting SAM 940-2GN data, contact the USAFSAM ESOH Service Center at esoh.service.center@wpafb.af.mil, or toll-free at 1-888-232-ESOH (3764).

5. Questions regarding this memorandum may be directed to Capt Andrew McUmber, at DSN 798-3317, or by email at andrew.mcumber@wpafb.af.mil.

ALAN C. HALE, Maj, USAF, BSC
Chief, Radiation Health Consulting Branch

3 Attachments:
1. USAFSAM SAM 940-2GN Data
2. Trend Line Analysis and Examples
3. Field Techniques

ATTACHMENT 1 – USAFSAM SAM 940-2GN DATA

1. Cs-137 Trial, Source: 158 mCi

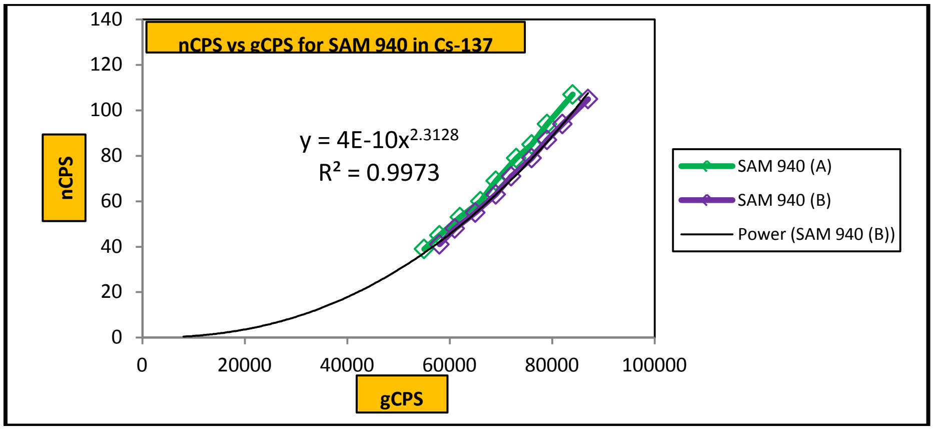

Figure 1: Cs-137 Results

2. Ra-226 Trial, Source: 11.4 mCi

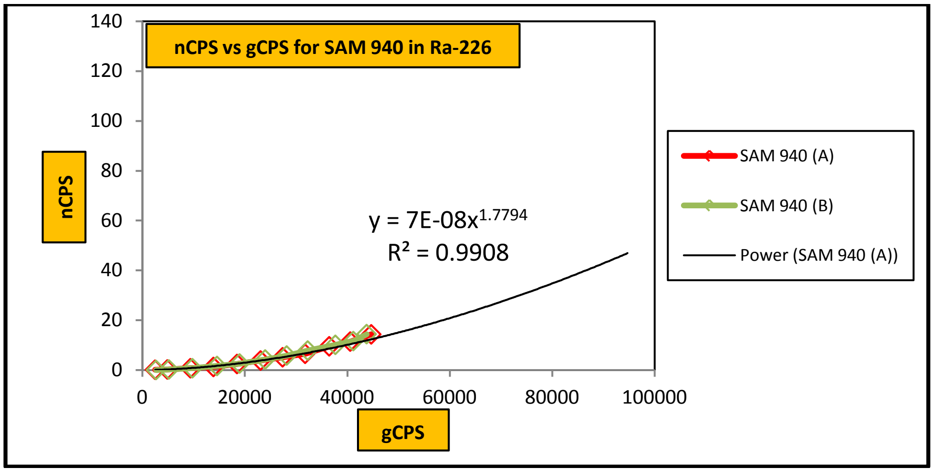

Figure 2: Ra-226 Results

3. Co-60 Trial, Source: 13.0 mCi

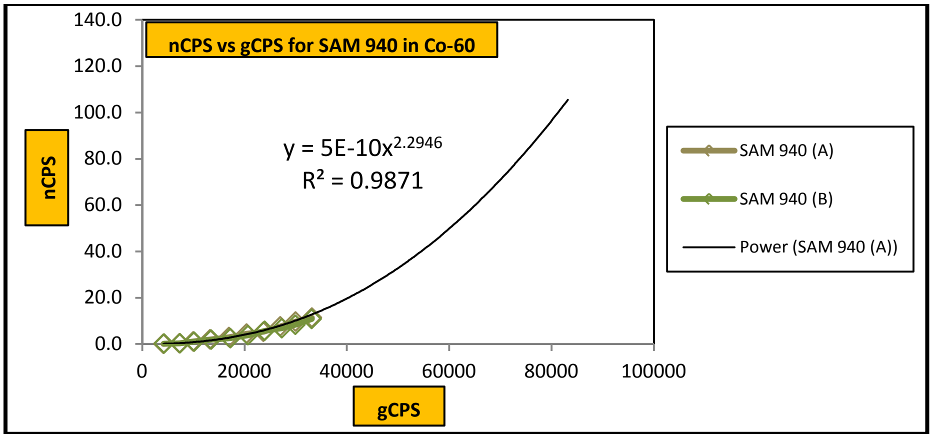

Figure 3: Co-60 Results

ATTACHMENT 2 – TREND LINE ANALYSIS AND EXAMPLES

1. Trend Line Analysis

When using the SAM 940-2GN in high-activity gamma environments, it is recommended that precautions are taken to ensure successful correction of neutron data. The equation below is recommended for estimating the false neutron count rate.

$$nCPS(estimate) = (5 \times 10^{-10}) \cdot (gCPS)^{2.3} \tag{1}$$

2. Examples for Data Interpretation

<u>Example A</u>. A field technician operating the SAM 940-2GN receives the following averaged count rate results from a spill involving known gamma-emitting radionuclides.

gCPS = 27K, nCPS = 6.5

Given the established worst-case scenario in Equation 1, do these readings warrant further examination for possibly unknown neutron-emitting isotopes?

For a gCPS reading of 27K, Equation 1 yields an nCPS (estimate) value of:

$$nCPS(estimate) = (5 \times 10^{-10}) \cdot (27000)^{2.3} = 7.4$$

Since nCPS (estimate) > data, the technician's readings <u>do not</u> warrant further examination.

<u>Example B</u>. An Airman responding with the SAM 940-2GN receives the following averaged count rate results from an accident involving known gamma-emitting radionuclides.

gCPS = 33K, nCPS = 2K

Given the established worst-case scenario in Equation 1, do these readings warrant further examination for possibly unknown neutron-emitting isotopes?

For a gCPS reading of 33K, Equation 1 yields an nCPS (estimate) value of:

$$nCPS(estimate) = (5 \times 10^{-10}) \cdot (33000)^{2.3} = 11.7$$

Since nCPS (estimate) < data, the technician's readings <u>are</u> cause for further examination.

ATTACHMENT 3 – FIELD TECHNIQUES

1. Accounting for nCPS in the Field

An additional method for determining the presence or absence of neutron radiation with the SAM 940-2GN involves the use of shielding placed between the source and the detector. The introduction of a metal (e.g., tin or lead) shield may serve as a barrier or shield, which will attenuate some of the gamma radiation; however, it will not appreciably affect the neutron count rate if a neutron emitter is truly present. After introducing a shield, if the neutron count rate decreases proportionally with the gamma count rate as predicted by Equation 1 (see Attachment 2), then it is likely that neutron radiation is not present.

2. Decision Matrix

Table 1 below can be used by BE personnel to qualitatively decide if the neutron count rate (nCPS) from the SAM 940-2GN is likely due to cross-talk or a neutron emitter.

Table 1: SAM 940-2GN Decision Matrix

Action	Outcome	Decision
Neutron count rate is estimated by use of Equation 1 based on gamma count rate	nCPS ≤ nCPS expected value	Neutron emitter is likely not present
	nCPS > nCPS expected value	Neutron emitter is likely present
Metal shield is placed between source and detector	nCPS decreases as a function of decreased gCPS	Neutron emitter is likely not present
	nCPS is unaffected or does not decrease as a function of decreased gCPS	Neutron emitter is likely present